REMARKS

1) Drawings (Paragraph 1 of the First Office Action)

The examiner has an objection under 37 CFR 1.83 (a) that drawings must show every feature of the invention specified in the claims but that the term from Claim 5 "separator" is not shown. (Claim 5 recites a "separator functioning to urge the movable covering to the non-contact mode".) The examiner proposes the language "Various separators may be used to insure..." in the specification, a suggestion for which the applicant thanks the examiner. The applicant has amended the specification as suggested, thus presumably obviating the need to amend the claims. If this is in error, the applicant will further amend the drawings.

Discussion:

The applicant respectfully points out that the examiner has clearly correctly understood the meaning of two passages found on page 13 of the original application at lines 15 through 17 and on page 14, lines 8 and 9.

> Non-conductive hinges 201 could be used to facilitate the separation, as could a piezoelectric strip.

> This can include non-conductive hinges 201 as shown, which are designed to collapse.

Thus, reference number 201of Figure 2A is in fact a separator. At greater length: the original application, page 8, lines 4 through 18.

> Experimentation has shown that the applied voltage can be lowered significantly before the film releases. Removal of the voltage results in physical separation and thus a low emissivity state. Experimentation has shown that physical separation by floating was acceptable. <u>Other means of insuring separation can be achieved with a release mechanism</u>. The coated film can be attached at all corners or simply at one edge. A piezoelectric strip attached to the cover film in which applying a voltage would cause them to expand, causing the entire structure to bend (bimorph). Other approaches would be <u>nonconductive hinges</u>, slight tension on the composite film at the edges so as to control "spring-back", a spring loaded or magnetically actuated plunger that simply moves the cover film out a small amount, etc.

The references to non-conductive hinges 201 refer to a separator, as the examiner has undoubtably understood.

<u>Example of Amendment</u>

Therefore, in accordance with the examiner's suggestion, the specification is amended to use phrases such as "Various separators may be used to insure…" This term is also used to refer to elements of the diagrams, thus obviating this grounds for rejection.

The following is a quote from a particular section pointed out by the examiner, page 14, <u>after being amended herein:</u>

> Various <u>separators may be used</u> [methods are possible] to insure that this gap G is sufficient to limit the heat transfer. <u>Separators</u> [This] can include non-conductive hinges **201** as shown, which are designed to collapse.

With the examiner's suggested amendment of the specification incorporated, the separator is referenced in the diagrams and thus the applicant believes that the drawings are more clearly in conformity due to this change in the specification.

2) <u>Specification (Paragraphs 2, 3, and 4) of the First Office Action)</u>

The examiner has objected to the abstract and specification of the disclosure stating that "it does not avoid using the phraseology and language often used in patent claims (such as term "means"), and because, even though the claims are drawn to an apparatus, the abstract fails to sufficiently summarize the structure of the inventive apparatus, and further because of the use of numerous trademark terms without proper demarking from the text of the marks used.

In accordance with the examiner's requirements, the applicant has edited the specification as follows: a) extraneous use of inappropriate language is minimized, b) the structure of the apparatus is further summarized without addition of new matter in the abstract, c) synonyms for "separator" have been replaced with the claimed term itself, and d) trademarked terms have been capitalized and generic specification thereof used.

3) <u>Claim Rejections – 35 U.S.C. § 112 (Paragraphs 5 - 8 of First Office Action)</u>

The examiner rejects claims 1 through 21 under 35 U.S.C. § 112. A number of terms are at issue, "high/low emissivity" (claims 1 through 21) and "high dielectric" and "high thermal conductivity" (claim 6), "inner/outer" (claims 8 through 21) and the use of the word "means" in certain claims.

a) Regarding the use of "high emissivity" and "low emissivity", the examiner admits that actual numerical values are provided in the original application (high greater than about 0.9 and low less than about 0.1) and yet the examiner objects on the grounds that certain objects may move in and out of these ranges depending upon external conditions. (The environment of space, where a space craft and the invention would be used, has a variable temperature based on shadow or light on the space craft skin as well as the density of any present atmosphere, and a wide range of additional factors the examiner has ignored.)

However for any given set of known materials and conditions the resulting body surface temperatures are easily calculated: there is no lack of specificity in regard to later users of the invention determining emissivity under specified conditions. Note that emissivity has been defined in relation to temperature as stated in the original application on page 12, lines 1 through 22 and page 13, lines 1 through 10.

> Fig. 1A is a depiction of the ESR (Electrostatic Switched Radiator) 1000 in the "OFF" state. The outer skin 100 of the craft radiates heat via radiation Rs. Thermal gap G acts as an insulator. Energy is radiated Rs by the outer skin 100, which has a low surface emissivity. Heat is

absorbed by the composite film 102 consisting of the dielectric 101 and the thin metallic surface coat 104. In this "OFF" position, the heat loss from the outer skin 100 is the energy lost from radiation emitted Rs minus the energy absorbed from the reflected radiated energy Ra of the composite film 102 (dielectric 101 and thin metallic surface coat 104) and minus the energy absorbed from the radiated energy Rb by the surface of the composite film 102 (dielectric 101 and metallic surface coat 104) at an unknown temperature. The composite film 102 (dielectric 101 and outer thin metallic surface coat 104) thus emits reflected radiated energy Ra back to the skin 100 and radiated energy Rb from the surface temperature. Energy is also transferred into space by radiated energy Rc from the high emissivity surface of the metallic surface coating 104. A steady state temperature will occur when the temperature of the dielectric 101 and metallic surface coat 104 reaches a temperature such that it's energy absorbed is equal to its energy radiated.

Fig. 1B is a depiction of the ESR 1000 in the "ON" state. In this state, the outer skin 100 of a craft is in close contact 103 (thermal contact) with the thin film dielectric 101 and its metallic coating 102. In this "ON" state heat is conducted away from the outer skin 100 of the craft at a very high level of efficiency and transferred into space by radiation Rc off the metallic surface 104 which is designed at a high emissivity.

Thus the applicant has already noted that emissivity varies with temperature and has specified that the emissivity as the claimed variable, not the temperature.

The invention concerns control of emissivity, not indirectly via temperature but as a variable in and of itself. The applicant is not claiming a single material or a single set of physical conditions, it is claiming a method of controlling emissivity.

More broadly, the applicant is free to use ordinary physical terms without specifying a complete set of conditions attached thereto, as the applicant is free to be his own lexicographer provided only that no violence is done to the ordinary meanings of words. The applicant has adopted the ordinary use of the term emissivity and is not required to specify what conditions will render what choices of materials or objects within this term and what without, the alternative would be to require the applicant to produce an impossible multi-variable table of hundreds of thousands or millions of different combinations of materials, surface and skin treatments, distances from the sun, local atmospheric density, other cooling mechanisms occurring on or under the surface, interior temperature, rotation rate and thus percentage of the time spent in the sunlight, and so on. The applicant provided in the original application not only reproducible results of laboratory testing but also examples of materials and conditions such as a 300 degrees Kelvin internal temperature, thin polymer films, sputtered gold, conventional paints and coatings, KAPTON or KYNAR brand polyimides, sputtered metal on a polymer, and so on. Page 6, lines 20 et seq of the original application is one of the examples:

Typical films could consist of an outside coating of copper with only 1000 angstrom to 25-50 micron thickness… The film itself is an insulator such as polyimide…

Materials and objects under conditions that cause their emissivity to be low or high (as defined in the application) fall within the scope of the claims.

The applicant has furthermore hereby amended one dependent claim to offer numerical values of high and low emissivity.

b) In regard to claim 6, and the use of the terms "high dielectric" and "high thermal conductivity", the applicant notes that examples of materials having precisely known and advertised properties (KYNAR and KAPTON brand polymers) is specified in the original specification at page 7, lines 1 through 8, in the same sentence containing the specification of these properties.

However, applicant has elected to moot this issue by broadening claim 6 by amendment herein. The modified version of claim 6 merely specifies merely that the material have a dielectric constant, a thermal conductivity and a dielectric strength. Since the term "high" is no longer used, there is no need to argue specification of the term "high" by reference to materials of known properties. As claim 6 remains indirectly dependent upon claim 1, it remains allowable

c) The examiner has also objected to the use of the terms "inner" and "outer" in describing the various layers of the space craft body and the movable covering/skin.

Rather than arguing that the inside and outside of a spacecraft are ordinarily quite distinct, the applicant instead notes that the examiner uses the phrase "...absent the recitation of a particular point of reference..." and thus assumes that "inner" and "outer" will be according their normal definitions given recitation of a point of reference. The applicant has therefore specified "outer" and "inner" layers of the movable covering in reference to the heat-emitting inside of the spacecraft. The applicant believes this obviates this ground for rejection.

d) The examiner has noted that the applicant utilized the term "means" in the claims and the applicant has modified the claims as necessary to use either full term "means for", or to alternatively describe structure.

4) <u>Claim Rejections – 35 U.S. C. § 102 (Paragraphs 9, 10, 11, 12 of First Office Action)</u>

The examiner presently rejects all claims over on US Patent No. 3,734,172 (herein the '172 patent) issued May 22, 1973 to Clifford.

The '172 patent is fundamentally different from the present application. While the present invention is a radiator, the '172 patent teaches a thermal flow switch. It is conceptually different, it is not located at the same place on the space craft, it acts to transmit heat based largely upon different principles, it does not disclose various times found in the claims and as a natural result of all these basal differences, <u>it has numerous structural differences</u>.

The '172 patent operates to vary the thermal conductivity of a wall. That is, it teaches that insulating sheets located inside of a space craft wall may be moved closer or further apart by means of electrostatic forces. This moving of sheets by means of electrostatic charges is a point of similarity which the examiner doubtless noted in citing the '172 patent. However, the result (specified in the abstract of the '172 reference and thereafter at numerous locations in the text) is to alter the <u>thermal conductivity</u> of the wall inside of which the '172 device is used. That is, the emissivity of the outside of the space craft at a given temperature of the outer surface of the wall is not implicated nor altered by this device, as the device is not located outside of the space craft at all. It is located inside the wall to carry out its function of altering thermal conductivity of the wall, and if any alteration in emissivity occurs, it is only due to changing the temperature of the wall. The '172 patent further lacks a "non-contact" mode. The representative figure of the '172 patent appears to show members out of contact, until the enlargement (reference numeral 2, a circular cross section of the wall) is examined. This is a cross section of the representative diagram and clearly shows the layers in contact with one another at numerous points. The text bears this out: the layers are urged apart by "spring forces", that is minute irregularities in the flexible material of the '172 members. Obviously, this spring force cannot carry the members entirely out of contact with each other, since they self generate the spring force.

The present invention, on the other hand, alters the emissivity of the space craft in reference to its environment and without the necessity of heating the wall to achieve greater emissivity. It does this by means of a movable <u>covering</u> of the space craft. A covering is not a component which can be used inside of the object it covers, unlike the

'172 patent which shows members located inside of the space craft wall. By covering the outside of the space craft either in a contact or non-contact mode, the present device alters the emissivity of the space craft (that is the radiation of heat away form the space craft).

Some structural differences may now be listed.

a) The '172 patent fails to teach a "covering", it teaches wall interior structures.

b) The '172 patent fails to teach a "non-contact mode".

c) The '172 patent fails to teach a high emissivity outer layer and a low emissivity inner layer of the covering, since it has no covering.

d) The '172 patent fails to teach a method of allowing a higher amount of heat to <u>radiate</u> from the object <u>at a given temperature</u> of the outside of the object. That is, the '172 patent simply does not teach changing emissivity without temperature changes, on the contrary, it teaches a method of changing the temperature.

e) The '172 patent does not disclose a distinct "separator" device enabling a non-contact mode.

f) The '172 patent teaches the use of "plastics" in the sheets which would not work for the present invention. "Plastics" work well at the spacecraft interior temperatures of the '172 patent but most plastics would not work at the spacecraft exterior temperatures of the present invention.

g) The '172 patent teaches crinkly sheets (having numerous small wrinkles therein) to provide springing action. The present invention teaches a sheet

which is described in the original specification, page 6, as being "pliable", at page 14, (referring to the Figures, which show a smooth sheet) it is stated that "In this position the thermal gap G is basically zero. Thus, the metallic surface coat 104 and thin film dielectric 101 are in direct contact with the outer skin 100 of the craft." Later on the same page, the covering is described as being "elastic". Elastic materials cannot be taught by the '172 reference, as elastic materials cannot hold a wrinkle. These are natural consequences of the differences between internal wall insulations ('172) and external coverings (the invention).

The applicant has made certain modifications to the claims. Firstly, the movable covering is specified to be outside of the space craft in amended claim 1, although as noted previously, a "covering" is inherently located "outside" of whatever it covers. This adds another distinction to the list above.

5) Hypothetical combination of '172 and other prior art cited to date. (No paragraph reference).

While the examiner relied upon the '172 reference only in a section 102 rejection, the applicant will proactively consider a section 102 rejection of the application over '172 and other patents cited by the examiner.

First, the applicant does not accept that the '172 patent can even be combined with patents relating to spacecraft external emissivity changes, since the '172 patent does

not alter emissivity but rather alters the internal structure of the wall and thus conductivity.

Most cited patents teach either mechanical devices such as large swinging panels or else teach various types of coatings having a variety of properties. These items may be safely ignored as not dealing with electrostatic changes to the exterior of the spacecraft.

US Patent No. 3,220,647 cited by the examiner (Riordan et al, herein the '647 patent) at least teaches some sort of moveable elements on the exterior of a spacecraft for control of emissivity. Use of electrostatic forces is not implicated: like the '172 patent, this item relates to temperature changes which cause the bimetallic plates to move. Moreover, like the '172 patent, this patent structurally does not teach a "covering" or "skin" such is described in originally filed claims 1 and 2, rather it teaches numerous small and curved bi-metallic plates arranged in parallel rows (col. 2, line 26). Thus the combination of the '172 and '647 patents does not teach an electrostatically movable covering or skin on the exterior of the spacecraft.

US Patent No. 5,806,800 (Caplin, herein the '800 patent) teaches mechanical radiator covers which may opened when a the spacecraft radiators are required to operate at high efficiency, and insulates the radiators when the craft is being warmed. These devices are mechanical, not electrostatic. They are large flaps but still do not meet the reasonable definition of a "covering" or "skin". They do not directly alter the emissivity of the surface of the spacecraft but rather operate to hide or expose radiators.

Conclusion

The patents cited to date by the examiner do not teach any item which implicates electrostatic control of the emissivity of the exterior of a spacecraft. The natural and obvious result is numerous structural differences between the invention and any combination of the art cited.

For all the foregoing reasons, applicant respectfully urges that the claims of the application are now in condition for immediate allowance, and such action is requested. The examiner is respectfully urged to contact applicant's counsel, Craig W. Barber, PO Box 16220, Golden, Colorado, 80402-6004, 303-278-9973, fax 303-278-9977, with any questions or comments.

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TITLE

Electrostatic Switched Radiator For Space Based Thermal Control

FIELD OF THE INVENTION

The present invention relates to an improved device for controlling the effective emissivity of a surface by use [means] of electrostatic attraction, which controls the thermal conductivity.

BACKGROUND OF THE INVENTION

Control of solar absorption and/or thermal emissivity is important for temperature control involving systems where radiation is the major heat control mechanism. Control of black body radiation and solar absorption, using a spectrally selective coating, will help control the temperature. But, when the heat load varies, active control of the thermal radiation is needed. Coolants have been used to conduct heat to an external radiator and can be controlled to block, or to be open, to piping. Louvers are another alternative that can be used to open or close. With a louver in one position, the exposed surface will have a high emissivity; alternately when the louvers is in the

other position, the exposed surface will have a lower emissivity and will radiate less heat. When radiators are fixed, as in present art, options including heat pipes, heat pump systems, capillary pump looped heat pipes and louvers can be effective but are expensive, heavy and bulky.

Electrostatic forces have been used previously in various applications.

U.S. Pat. No. 4665463 (1986) to Ward *et al.* describes an electrostatic chuck for holding a semiconductor wafer, comprising a dielectric layer on a supporting electrode. A potential is applied between the wafer and the electrode and the dielectric is loaded with thermally conductive material to improve dissipation of heat generated in the wafer during a processing treatment such as exposure to an electron beam.

U.S. Pat. No. 4771730 (1987) to Tezuka *et al.* describes a vacuum processing apparatus with a vacuum vessel within which a work to be processed is drawn and held fixed on a specimen table by an electrode functioning doubly as an electrostatic chuck, to which is connected a gas feeding pipe for feeding a gas affording good heat transmission between the mutually contacting surfaces of the work and the electrode to control the temperature of the work.

What is needed is a smaller, less expensive, flexible, lighter weight, higher performance, and more reliable solution. The present invention solves these problems with use of an electrostatic switched radiator.

SUMMARY OF THE INVENTION

The main aspect of the present invention is to provide an electrically switched radiator for space based thermal control by <u>use</u> [means] of an electrostatic hold-down or release of a thin composite film to control inner compartment craft/spacecraft temperature.

Another aspect of the present invention is to provide thermal control by producing a large change in effective emissivity when switching the device from the "off" (non-radiating) to the "on" (radiating) stage.

Another aspect of the present invention is to provide a high emissivity composite film to control craft/spacecraft skin temperature.

Another aspect of the present invention is to provide a <u>device</u> [means] for switching the effective emissivity from a low to a high value and visa versa via contact/non-contact with a surface to be cooled.

Another aspect of the present invention is to provide for a thin composite film which is flexible for good contact with the outer skin of the craft.

Another aspect of the present invention is to provide a low cost, low weight, high performance, high reliability and small size electrostatically controlled radiator for thermal control of craft/spacecraft temperatures.

Other aspects of this invention will appear from the following description and appended claims, reference being made to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

The present invention utilizes a high emissivity composite film to control craft/spacecraft skin temperature. The electrostatic hold-down switches the mode of heat transfer from the craft/spacecraft skin from a conduction mode to a radiation mode and back. The device is referred to as the "Electrostatic Switched Radiator" or ESR. The ESR is very lightweight and has demonstrated with experimentation the capability to switch the emissivity from below 0.1 to above 0.95. Emissivity is simply the ratio of the actual emitted radiance to that of an ideal blackbody. Emissivity ranges from 0 to 1 where 1 would be a blackbody. Emissivity

can also vary with wavelength for any particular substance. For example, the emissivity for a water droplet decreases as the wavelength decreases.

The ESR construction is simple and lightweight. It consists of a thin polymer film, with a weight of less than a few hundred grams/m^2. The film can be anchored to the craft/spacecraft at the edges. The cover film consists of a high dielectric constant insulator with a good dielectric strength and is coated on its outer surface with an electrically conductive thin layer. The outer surface of the ESR is constructed to have a very high emissivity, ideally with low visible absorbance. This combination can be achieved with an appropriate paint or, for better performance, a multi-layer thin film designed for very low visible absorbance and high emissivity. The top surface or "skin" of the craft/spacecraft, to which the ESR will be "in contact" or "not in contact" should have a very low emissivity, i.e. sputtered gold.

Basic heat control is simple and highly effective. When the ESR is turned on, the emitting surface is in good thermal contact with an inner surface skin (such as the outer skin of a spacecraft). This results in good heat conduction between the craft surface (skin) and the ESR such

that the emitting surface of the film is at the craft skin temperature. The emitting ESR surface radiates at the "skin" temperature (high emissivity state). When the ESR is turned off, the film moves away from the skin (is not in contact) and the heat flow is only radiation from the inner surface skin (low emissivity). Thus, once it reaches equilibrium, the film can only radiate the heat it absorbs which is limited to radiation from the inner surface skin. The inner surface skin is fabricated with a low emissivity and thus in the released state, the outer skin emissivity doesn't change, however it's temperature drops and the result is a drop in the radiated energy. This approach avoids the need for an infrared (IR) transparent conductor, which is always difficult since transparent conductors (wide band gap semiconductors with high electron concentration) have significant absorption in the IR.

The ESR requires minimal material requirements and the system is compatible with conventional paints and coatings for full utilization in low solar absorbance, high emissivity coatings. Typical films could consist of an outside coating of copper with only 1000 angstrom to 25-50 micron thickness. A sputtered metal on a polymer will improve hold-down via a more pliable structure and allow

operation at a lower applied voltage. The film itself is an insulator such as polyimide ([Kapton]<u>for example, KAPTON brand polyimide</u>) and requires a high dielectric constant, high thermal conductivity, and high dielectric strength properties. Other films such as [Kynar]<u> KYNAR brand polymer film</u> are also alternatives. The ESR operates as a high quality capacitor with a dielectric (film) between two layers of metal (film metallic coating and craft metallic coating). The surface area (radiating area) of the ESR is calculated to dissipate heat needed to control the internal temperature of the vehicle or craft. Surface area is selected as a function of heat generated in order to determine the amount of heat to be radiated. The ESR can be subdivided into sectional areas depending on design requirements. The skin or area of contact, such as the outer skin of a craft, is required to be metallic or metallic coated (typically aluminum). Typical internal craft temperatures are often controlled around 300 degrees Kelvin (Room Temperature). The heat generated inside will raise the internal temperature and the ESR will dissipate the heat to control the internal temperature to room temperature.

Switching a DC voltage controls the "on" versus the "off" state of the ESR. The ESR will operate effectively

with moderate levels of DC voltage (typically 100-500 VDC). When voltage is applied between the outer conductive surface of the film and the outer conductive of the craft, the film is attracted to the craft surface and a high emissivity level results transferring heat. Experimentation has shown that the applied voltage can be lowered significantly before the film releases. Removal of the voltage results in physical separation and thus a low emissivity state. Experimentation has shown that physical separation by floating was acceptable. [Other means of insuring] In the alternative, separation can be achieved with a release mechanism or separator. The coated film can be attached at all corners or simply at one edge. A piezoelectric strip attached to the cover film in which applying a voltage would cause them to expand, causing the entire structure to bend (bimorph). Other separators include [approaches would be] nonconductive hinges, slight tension on the composite film at the edges so as to control "spring-back", a spring loaded or magnetically actuated plunger that simply moves the cover film out a small amount, etc.

Early experimentation by the inventor has shown individual ESR devices can be fabricated with measured emissivity changes of 0.74 or more. Additionally, it has

been shown that ESR devices can be fabricated with achieved high value emissivity levels greater than 0.9 and low value emissivity levels of lower than 0.1. Thus devices with these characteristics would generate a change of greater than 0.8 in switched emissivity levels.

Actual test measurements of a working device contained within a vacuum bell jar were performed using a copper block with an area consisting of a flat black painted strip as the high emissivity reference, an area of bare copper as a low emissivity reference, and an area with the ESR. Measurements were taken using an <u>INFRAMETICS 625 brand of</u>[Inframetics 625] imager, which is a camera sensitive from 8 to 14 microns. Test results showed that, within the limits of the test setup, the "on" state of the ESR was approximately the same as the black painted substrate and the "off" state of the ESR was approximately the same energy as the bare copper. The black painted area was estimated to have an emissivity of approximately 0.95 and the bare copper an emissivity of less than 0.01. Thus, within the limits of the experimental measurements, the high emissivity "on" state (with electrostatic hold-down) was shown to have the same emissivity as the black painted strip and the low emissivity "off" state (with no electrostatic hold-down) was shown to

have the same emissivity as the bare copper. This test showed that electrostatic hold-down would insure good thermal contact and that a vacuum system could produce a sufficiently low pressure to eliminate or minimize thermal conduction from the air.

Since this measurement is sensitive to the wavelength of the detector, additional measurements were made in which measurements of the heat loss were used to determine the emissivity. With this measurement, the sample is placed on a thermal control plate and the heat loss is measured by measuring the power required to maintain temperature and is basically a calorimetric approach. The heat loss with ESR switching gives a very accurate measure of a change of emissivity. Absolute values of emissivity require a calibrated sample, which used a sputtered gold film as the "zero" emissivity point and a black paint for the high emissivity value ($\varepsilon_{.}$~0.9).

Fig. 3 (below) shows measured results for a sample consisting of a cover film with a thin aluminum film. For this measurement, the voltage was applied while the sample was warm and showed a change of the effective emissivity of 0.74. This test showed that electrostatic hold-down would insure good thermal contact.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1A, 1B is a depiction of the ESR in the "OFF" and the "ON" states, respectively.

Fig. 2A is a cross-sectional view of the ESR with a voltage source and switch and the ESR in the "OFF" position.

Fig. 2B is a cross-sectional view of the ESR with a voltage source and switch and the ESR in the "ON" position.

Fig. 3 is a graph of power input measurements of a thin metallized ESR.

Fig. 4 is a depiction of a craft with two ESRs attached, one in the "ON" and one in the "OFF" position.

Before explaining the disclosed embodiment of the present invention in detail, it is to be understood that the invention is not limited in its application to the details of the particular arrangement shown, since the invention is capable of other embodiments. Also, the terminology used herein is for the purpose of description and not of limitation.

Detailed Description of Drawings

Fig. 1A is a depiction of the ESR **1000** in the "OFF" state. The outer skin **100** of a craft radiates heat via radiation **Rs**. Thermal gap **G** acts as an insulator. Energy is radiated **Rs** by the outer skin **100**, which has a low surface emissivity. Heat is absorbed by the composite film **102** consisting of the dielectric **101** and the thin metallic surface coat **104**. In this "OFF" position, the heat loss from the outer skin **100** is the energy lost from radiation emitted **Rs** minus the energy absorbed from the reflected radiated energy **Ra** of the composite film **102** (dielectric **101** and thin metallic surface coat **104**) and minus the energy absorbed from the radiated energy **Rb** by the surface of the composite film **102** (dielectric **101** and metallic surface coat **104**) at an unknown temperature. The composite film **102** (dielectric **101** and outer thin metallic surface coat **104)** thus emits reflected radiated energy **Ra** back to the skin **100** and radiated energy **Rb** from the surface temperature. Energy is also transferred into space by radiated energy **Rc** from the high emissivity surface of metallic surface coating **104**. A steady state temperature will occur when the temperature of the dielectric **101** and metallic surface coat **104** reaches a

temperature such that it's energy absorbed is equal to its energy radiated.

Fig. 1B is a depiction of the ESR **1000** in the "ON" state. In this state, the outer skin **100** of a craft is in close contact **103** (thermal contact) with the thin film dielectric **101** and its metallic coating **102**. In this "ON" state heat is conducted away from the outer skin **100** of the craft at a very high level of efficiency and transferred into space by radiation **Rc** off the metallic surface **104** which is designed at a high emissivity..

Fig. 2A is a cross-sectional view of the ESR **1000** with a voltage source **204** and switch **205** open and thus the ESR **1000** in the "OFF" position. The metallic surface coat **104** and thin film dielectric **101** are separated from the outer skin **100** of the craft by a thermal gap **G**. Non-conductive hinges **201** could be used to facilitate the separation, as could a piezoelectric strip. A DC circuit consists of a DC voltage source **204**, a switch **205** in the open position, an outer skin contact point **207**, a connector **202** and insulator **206** and a wire contact **203** to the metallic surface coat **104**.

Fig. 2B is a cross-sectional view of the ESR **1000** with a voltage source **204** and switch **205** in the "ON" position. In this position the thermal gap **G** is basically zero. Thus, the metallic surface coat **104** and thin film dielectric **101** are in direct contact with the outer skin **100** of the craft. Various separators may be used [methods are possible] to insure that this gap G is sufficient to limit the heat transfer. Separators [This] can include non-conductive hinges **201** as shown, which are designed to collapse. Normal elasticity of the cover film when stretched and mounted at the ends may be sufficient to insure such a gap. A piezoelectric strip attached to the cover film as previously described could also be used. In this "ON" position the DC voltage source **204** pulls the thin film dielectric **101** and its metallic surface coat **104** into thermal contact with the outer skin **100**. The ESR **1000** transfers heat from the outer skin **100** and radiates the heat into space by the high emissivity surface of the metallic surface coat **104**. As also shown in Fig. 2A, is a DC circuit consisting of a DC voltage source **204**, a switch **205** in the closed position, an outer skin contact point

207, a connector **202** and insulator **206** and a wire contact **203** to the metallic surface coat **104.**

Fig. 3 is a graph of power input measurements of a thin metallized ESR as was discussed above; the sample tested having a change of emissivity of 0.74. When the ESR was switched from a low "off" state **300** to a high "on" state **301** it can be seen that power requirements decreased

Fig. 4 is a depiction of a craft **400** with two ESRs attached, one in the "ON" position **405** and one in the "OFF" position **406.** Energy released within a craft can come from electronics **403** and/or human occupants **404** which would increase the internal craft temperature if no control were present. Electronic switching sensors **401, 402** would allow for electrostatic switching of the ESRs **405, 406** by allowing a voltage to be "on" or "off". Contact points for the electronic sensor **401** are at the outer skin **408** and at the metallic surface **407** of the ESR **406,** which is shown in the "OFF" or non-contact mode. Thus, little or no energy is radiated into space **S** as previously discussed. Contact points for the electronic sensor **402** are at the outer skin **410** and at the metallic surface **409** of the ESR **405,** which is

shown in the "ON" or contact mode. Thus, energy **Rc** is radiated into space **S** as previously discussed.

Although the present invention has been described with reference to preferred embodiments, numerous modifications and variations can be made and still the result will come within the scope of the invention. No limitation with respect to the specific embodiments disclosed herein is intended or should be inferred.

ABSTRACT

A thermal control device for controlling the temperature of a craft/spacecraft is [by means of] an electrostatic switch causing [to change the mode of heat transfer of the craft/spacecraft skin from conduction to radiation. The change is by means of] a large change in apparent emissivity. A flexible covering has a high emissivity and makes close contact with the surface of the spacecraft when electrostatically attracted thereto, when the covering is out of contact, the spacecraft surface emissivity controls radiation. The device can operate with moderate levels of DC voltages. Application of voltage results in high emissivity while removal of voltage allows a separator to move the covering out of contact and thus results in low emissivity.